HEAVY METALS IN ALIGARH'S URBAN SOILS: AN OVERVIEW OF HEALTH RISKS AND POLLUTION ASSESSMENT

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Abstract

Pollution of urban soils with heavy metals is a major threat to human and environmental health around the world. In this review, we will look at heavy metals in urban soils, specifically in the Aligarh example, and we will synthesize what is already known about their origins, patterns of distribution, health hazards, pollution assessment tools, and mitigation strategies. Industrial processes, vehicle emissions, and past land usage are the main causes of heavy metal accumulation in urban soils. These pollutants cause cancer, respiratory problems, and developmental delays in both people and ecosystems. Factors including local environmental variables and the distance to pollution sources affect the spatial variability of contamination levels in metropolitan areas. Assessment approaches that utilize modern analytical techniques, such as GC-MS and ICP-MS, are essential for precisely measuring contamination levels and providing guidance for remediation activities. Soil management, phytoremediation, and regulatory frameworks are effective mitigation options that reduce pollution levels and protect human health. Government officials and city planners around the world can protect metropolitan areas from heavy metal pollution if they take the time to learn about and resolve these complexities.

Keywords: *Heavy Metals, Aligarh's, Urban Soils, Health Risks, Pollution, Soil Management*

1. INTRODUCTION

Heavy metal contamination is a global concern due to the growing population and industrial, agricultural, and domestic activities [1]. The industrial revolution, urbanization, and economic globalization have exacerbated environmental damage caused by heavy metal contamination, affecting food security and human health. While certain heavy metals are necessary for all living things, too much can be harmful. Natural weathering and volcanic activity can enrich heavy metals, but anthropogenic activities and high levels of contamination are the most significant sources. Manufacturers, especially in populated countries, often do not treat their waste before releasing it into open land or water bodies. Agriculture practices, such as using wastewater for irrigation and adding manures and sewage sludge, increase heavy metal bioavailability and transfer them to vegetables and groundwater, negatively impacting human health.

1.1 population of Aligarh

Aligarh, located in the Indo-Gangetic basin, has a predominantly agricultural population with a total harvested area of 565,553 acres. However, industrial activity and urbanization have rapidly increased, with 5506 major factories and small-scale industries by 2018. This study evaluates heavy metal pollution in the soil, water, and vegetation of Aligarh, highlighting potential health risks associated with human exposure to these metals.

1.2 Background of Heavy Metals in Urban Environments

Heavy metals, such as lead, cadmium, mercury, and arsenic, pose significant environmental and health risks in metropolitan areas due to their long-lasting presence in soils and infiltrating the food chain [2]. These metals, which can persist in urban soils for years and infiltrate the food chain, pose a threat to human health and ecosystems. Effective management techniques are crucial to reduce these risks and ensure sustainable growth in urban areas.

1.3 Importance of Studying Urban Soil Pollution

Researching urban soil pollution is crucial due to the concentration of pollutants from human activities and industries in metropolitan areas. These pollutants can build up in soil, endangering human health through direct contact or ingestion. Urban soils also affect groundwater quality and ecosystems. Understanding the degree and dispersion of contaminants helps evaluate environmental hazards and develop effective mitigation solutions. It also influences policy and urban planning decisions for sustainable development methods to reduce pollution and protect public health.

2. HEAVY METALS IN ALIGARH'S URBAN SOILS

2.1 Types and Sources of Heavy Metals

Heavy metals, such as chromium, lead, cadmium, iron, arsenic, cobalt, mercury, copper, and zinc, are classified as necessary or non-essential. Important heavy metals are less dangerous in small concentrations and serve as coenzymes in biological processes. Non-essential heavy metals pose serious risks to living organisms.

Figure 1: Heavy Metal [3]

- **Heavy metal toxicity**

Albeit certain heavy metals are necessary for human science, their sum can have unexpected unfortunate results on health and the body's systems. Despite having positive health impacts, research demonstrate that heavy metals are cancer-causing agents. These metals are being dissolved and posing a serious risk to human health because of their entrance into the pecking order as air, water, and soil contaminants, which can also harm cells and increase the risk of malignant growth [4]. The Global Office for Research on Disease indicates that superfluous heavy metals (Album, Cr, and As) are significant carcinogens.

- **Sources, exposure, and environmental impacts of lead**

Lead sources vary across nations due to historical and contemporary uses of lead products. In countries where unleaded gasoline is used, people have lower blood lead levels. Pregnant women in Bangladesh have higher blood lead levels than in other countries, with over 30% having levels over 5 µg/dL. Food storage cans are the primary source of lead exposure, with lead soldering found in 18% of cans. Chinese children receiving lead treatment have higher blood lead levels, driven by industrial sources and Chinese medication. Lead poisoning in children is difficult to diagnose due to nonspecific symptoms. Australian children have higher lead levels due to dishwashing powder in older homes built before 1940.

2.2 Distribution Patterns in Urban Soil

- **Spatial Variability**

Urban pollutants are spatially variable, often forming hotspots near sources like manufacturing plants, transit hubs, and high-traffic areas. These areas are the main sources of contaminated soil due to air deposition, paved surface runoff, and direct emissions. Wind patterns and regional topography influence the distribution of pollutants, affecting airborne concentration and microclimates [5]. Understanding these dynamics is crucial for evaluating environmental hazards and implementing targeted remediation measures to reduce the negative effects of urban soil contamination on ecological integrity and public health.

- **Depth Profiles**

Urban soil contamination concentrations vary significantly at different depths due to direct deposition of pollutants from air emissions and impermeable surfaces. Concentrated pollution near industrial areas and busy intersections is particularly noticeable. Contaminants, especially mobile and soluble ones, can move deeper into the soil profile, spreading pollution below the surface, affecting groundwater quality and creating long-term environmental hazards. Understanding these depth-dependent fluctuations is crucial for effective soil management and remediation efforts.

- **Land Use History**

Historical land use significantly affects urban soil contamination, with areas with industrial activity, garbage disposal, or agricultural operations often having higher levels of pollutants. Contamination can persist after operations, and leaching from buried materials can continue. Long-term land use changes, such as redevelopment or industrial conversion, can alter contamination distribution patterns [6]. These changes can affect exposure risks and the need for environmental evaluations and remediation plans to ensure sustainable urban growth and public health.

3. HEALTH RISKS ASSOCIATED WITH HEAVY METALS

3.1 Toxicity of Heavy Metals

Heavy metals can negatively impact soil, water, and the air, affecting pH, variety, porosity, and composition. They can also reduce farming efficiency and loss of vegetation. Water quality and availability pose significant risks to ecosystems and humans. Elevated heavy metal concentrations in the atmosphere can cause health issues like respiratory infections, cardiovascular disease, and early death. Plants can be damaged, obstructing biochemical processes like photosynthesis and causing damage to roots [7]. Animals exposed to heavy metals may experience decreased body weight, kidney and liver damage, shortened life spans, increased oxidative stress, changes in cell composition, and DNA damage. In humans, heavy metals can cause lung effects, liver abnormalities, renal damage, and various cancers.

Figure 2: Risks To Health Related to Heavy Metal [8]

- **Toxicity of lead (Pb)**

Lead is the most significant toxic heavy metal in the environment, causing health issues and environmental contamination. Industrial operations like burning fossil fuels, mining, smelting, manufacturing, and recycling contribute to lead contamination. Inorganic lead can enter the body through inhalation, smoking, or consuming food and water. Organic compounds may also be absorbed.

- **Toxicity of cadmium (Cd)**

Cadmium, a common industrial compound, is used in the plastics industry for plastic stabilizer, color pigments, alloys, glass, electroplating, welders, and rechargeable batteries. It is also emitted from mining and smelting. Exposure to cadmium can be ingestion of food or drink, inhalation of contaminated dust, and cigarette smoking. Dermal exposure is not a health risk as the metal cannot pass through the skin's protective layer.

- **Toxicity of arsenic (As)**

Arsenic, a significant heavy metal, is found in nature as arsine and metalloid in both organic and inorganic forms. Its primary inorganic forms are trivalent form arsenate ($As3+$) and pentavalent form arsenate ($As5+$). Methylated metabolites include trimethyl arsine oxide, dimethylarsinic acid (DMA), and monomethylarsonic acid (MMA) [9]. Organic arsenic compounds in seafood are less hazardous, while inorganic arsenic compounds in water are more poisonous.

The "exposure route" refers to the way a pollutant enters the human body, with land use and adjacent areas affecting potential routes. People can be exposed to pollutants through ingestion, inhalation, skin contact, and radiation exposure from the outside. Ingestion involves the oral consumption of radioactive and chemical pollutants found in food, soil, groundwater, and surface water. Inhalation involves the process of breathing in pollutants from the air, including those released from soil, groundwater, and surface water. Skin contact involves contact with pollutants found in soil, water, sediments, and other media. Radiation exposure from the outside is different from chemical pollutants, as alpha particles do not penetrate the skin and do not travel very far in the air. Assessing the viability of each exposure route is crucial for each potential exposure point and population.

3.3 Health Effects on Human and Environmental Health

- **Impacts on Human Health:**

Urban soil pollutants can cause immediate health issues like skin irritation, respiratory problems, and gastrointestinal pain due to direct contact or ingestion. Chronic exposure to pollutants, such as heavy metals like lead, cadmium, and arsenic, over time can lead to higher cancer risk, neurological impairments, developmental delays, and reproductive issues. Pregnant women, older people, and vulnerable groups like youngsters are particularly vulnerable due to their immature immune systems or developing systems.

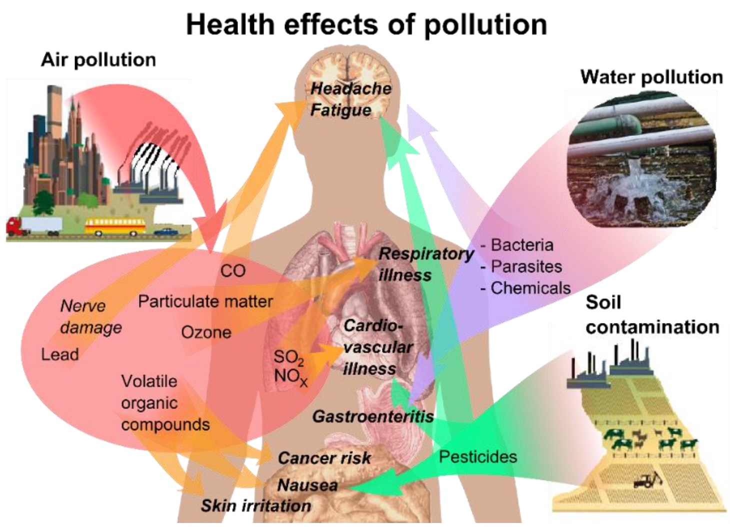

Figure 3: Health Effect of Pollution [10]

- **Effects of the Environment on Health:**

Urban soil contaminants pose a significant threat to the environment by disrupting microbial populations, affecting plant growth and production, and exposing humans and wildlife to toxins. Contaminants can also seep into surface or groundwater sources, deteriorating water quality and endangering aquatic life and ecosystems. Heavy metals and persistent organic pollutants (POPs) exacerbate these environmental effects. To mitigate soil contamination, a multifaceted strategy including sustainable urban development, land use planning, and soil testing and monitoring is needed. Remediation methods, such as soil cleaning and phytoremediation, can help reduce contamination level [11]. Regulatory frameworks enable enforcement of soil quality requirements, monitoring pollution control measures, and raising public awareness of health risks associated with contaminated urban soils.

4. POLLUTION ASSESSMENT METHODS

4.1 Sampling and Analytical Techniques

Urban soil pollution assessment methods use meticulous sampling and analytical processes to monitor pollutant levels and evaluate environmental risks. Sampling tactics include selecting representative locations based on factors like topography, soil composition, and proximity to pollution sources. Analytical procedures like GC-MS, ICP-MS, and AAS measure heavy metals, organic pollutants, and contaminants. These techniques provide essential information for risk assessment, remediation planning, and identifying contaminants. Quality assurance and control procedures reduce soil pollution's negative effects on human health and the environment, supporting regulatory decision-making.

4.2 Regulatory Standards and Guidelines

Soil contamination in metropolitan areas necessitates strict regulations and rules from government and international organizations [12]. These standards set limits for pollutants in soil, including pesticides, heavy metals, and organic compounds. They outline sampling procedures, analytical methodologies, and thresholds for contaminants. These standards also guide land use planning laws, pollution control measures, and remediation procedures. They promote public awareness and stakeholder participation, enabling policymakers, scientists, and the community to address soil contamination challenges. Regular updates ensure these standards remain relevant, promoting sustainable urban development and public health.

4.3 Case Studies or Previous Research in Similar Contexts

Case studies and research on soil pollution in metropolitan areas provide valuable insights into the complex nature of the issue [13]. These studies examine pollution patterns in cities with industrial activities, identifying hotspots near manufacturing facilities, transit hubs, and historical garbage disposal sites. They measure contaminants like heavy metals, PHAs, and POPs using field surveys, soil sampling, and advanced analytical techniques. The distribution and permanence of contaminants are influenced by land use history and urban development patterns. These studies also examine the effectiveness of remediation techniques in reducing soil pollution, influencing policy decisions and sustainable urban planning practices.

5. MITIGATION AND REMEDIATION STRATEGIES

5.1 Current Practices and Challenges

Current Practices

Monitoring and Evaluation of Soil:

Regular monitoring and evaluation of soil quality using advanced analytical methods like GC-MS and AAS can help identify pollution hotspots and evaluate hazards [14].

Prevention and Control of Pollution:

Implementing industry compliance initiatives and regulatory frameworks for pollution prevention solutions, utilizing best practices in industrial processes, waste management, and emissions reduction to reduce soil contamination.

Technologies for Remediation:

Utilizing physical, chemical, and biological remediation strategies, such as barrier systems, soil capping, excavation, oxidation, and bioaugmentation, can effectively reduce pollution scenarios [15].

Challenges

Expense and Resources:

The high expenses associated with monitoring, regulatory compliance, and remediation technologies, coupled with limited resources and financing, pose significant challenges for large-scale urban remediation projects [16].

Technical Difficulty:

Technical difficulties in determining and implementing effective remediation methods for various soil types and contaminants, along with potential synergy and interactions between pollutants, necessitate comprehensive treatment strategies [17].

Participation of Stakeholders and Regulatory Compliance:

The regulatory structures and authorization procedures may delay remediation initiatives, necessitating stakeholder engagement and community involvement to ensure transparency and resolve issues.

Effects on the Environment and Society:

Remediation operations may have environmental and social impacts, including soil disturbance, energy use, and secondary waste production, which can negatively impact public health, community views, and property values [18].

5.2 Potential Solutions for Reducing Heavy Metal Contamination

To reduce heavy metal contamination in urban soils, a multidimensional strategy involving preventative measures, remedial procedures, and environmentally responsible behaviors is needed. Preventative efforts focus on reducing industrial emissions and improving waste management [19]. Remediation uses physical, chemical, and biological methods, with nano and electrokinetic technologies potentially improving effectiveness.

Table 1: Comparative Analysis of Heavy Metal Contaminated Soil Remediation Techniques

Authors	Construct	Methods	Service Context	Key Findings
Liu et al. (2018) [20]	Overview of remediation techniques for heavy metal-contaminated soils	Phytoremediation, chemical stabilization, bioremediation	Principles and applicability of remediation strategies like phytoremediation, chemical stabilization, and	Comprehensive discussion on various remediation strategies and their applicability in different

			bioremediation. Emphasizes effectiveness and limitations in diverse environmental contexts.	environmental conditions.
Wang et al. (2021) [21]	Green remediation strategies for heavy metal-contaminated soils	Phytoremediation, biochar application, microbial remediation	Review of environmentally friendly approaches focusing on sustainability and benefits for soil health and ecosystem restoration.	Emphasis on evaluating the feasibility and sustainability of green remediation strategies such as phytoremediation, biochar application, and microbial remediation.
RoyChowdhury et al. (2018) [22]	Heavy metal pollution and remediation from a green chemistry perspective	Nanotechnology-based remediation, electrokinetic remediation, combined approaches	Discussion on innovative methods to mitigate heavy metal pollution using green chemistry principles, aiming to minimize environmental impact and effectively treat contaminated sites.	Coverage of advanced remediation approaches like nanotechnology-based and electrokinetic remediation, highlighting their potential in reducing environmental impacts.
Rajendran et al. (2022) [23]	Various remediation approaches for heavy metal contaminants removal	Chemical precipitation, physical separation, phytoremediation, electrokinetic	Critical review evaluating efficiency, applicability, and sustainability of remediation methods across	Comprehensive evaluation of conventional and advanced remediation techniques such as phytoremediation,

		remediation, nanoremediation	different environmental settings.	electrokinetic remediation, and nanoremediation, emphasizing the importance of selecting appropriate methods based on specific site conditions and types of contaminants.
Wang et al. (2021) [24]	Electrokinetic technology for remediation of heavy metal-contaminated soils	Electrokinetic remediation	Review of mechanisms underlying electrokinetic remediation and factors influencing its effectiveness. Case studies and experimental findings provided.	Focus on understanding the mechanisms and practical application of electrokinetic remediation in treating heavy metal-contaminated soils, including insights into key factors influencing its efficiency and limitations in real-world scenarios.

Green infrastructure and soil amendments reduce contamination, while rigorous monitoring ensures environmental compliance. Public education and stakeholder engagement promote community awareness and participation in soil management techniques, promoting healthier urban settings.

6. CONCLUSION

Heavy metal pollution in urban soils, especially in Aligarh, is a serious risk to the environment and public health because of industrial processes, car emissions, and past land usage. This review emphasizes how dangerously heavy metals like lead, cadmium, and arsenic affect ecosystems and human health in addition to building up in urban soils. Urban areas exhibit spatial variability in contamination, which emphasizes the significance of focused remediation efforts and localized pollution assessment. Reducing contamination levels and protecting public health require effective mitigation strategies, such as soil management practices and phytoremediation. Establishing guidelines and enforcing compliance are crucial functions of regulatory frameworks, which guarantee that soil quality stays within acceptable bounds [25]. Going forward, the effectiveness of remediation can be improved, and healthier urban environments resistant to the effects of heavy metals can be promoted, by combining sustainable practices with cutting-edge technologies like electrokinetic remediation and nano remediation. By tackling these concerns thoroughly, policymakers and urban planners may limit the detrimental consequences of heavy metal contamination and support sustainable urban growth globally.

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